Design of Ultra Wideband Band-pass (UWB) Filter Using Microstrip Line and Complementary Split Ring Resonators (CSRRs)

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ABSTARCT
In order to fulfill the need of miniaturized electronic filter that can be a part of automotive radar system is proposed in this paper. The suggested filter has two quarter wavelength long parallel coupled line sections with an attachment of Complimentary Split Ring Resonators (CSRRs) and stepped impedance open circuit stub which are connected in shunt at the center. This arrangement of components provides sharp selectivity for the range of 22 GHz to 29 GHz. Proposed filter is a combination of two already designed UWB filters with precised parameters. Therefore it is bound to have low insertion loss and better out of band performance.

Keywords
UWB, bandpass, filter, microstrip, CSRRs

1. INTRODUCTION
As soon as the Federal Communications commission (FCC) publicized the frequency range for Ultra Wideband to be from 3.1 GHz to 10.6 GHz in the year 2002, the need for UWB bandpass filter that works perfectly in that particular frequency slot rised. For radio applications the range for UWB is limited from 22 GHz to 29 GHz [1]. Since when the spectrum was allocated, a lot of researchers and scholars have tried to put forward certain filter designs that not only fulfills the electrical requirements of the filter but are low in cost, simple in structure and works efficiently in the desired frequency range. Ultra wide band employs a wide bandwidth which is typically 20% of the central frequency or even greater. It is used for short range high speed communication. It supports a bit rate greater than 100 Mbps within a 10-meter radius for wireless personal area communications. An UWB bandpass filter can be employed in UWB RF front end module. The advantages of UWB include low-power transmission, robustness for multi-path fading and low power dissipation. The low power transmission of the UWB is the key characteristic that allows it to coexist with other wireless networking standards such as 802.11 LAN, 802.16 MAN and WAN. The major applications of the UWB is in the areas of communication, radar, precision geo-location. FCC limits operation of vehicular radar to the 22 GHz to 29 GHz band using directional antennas on terrestrial transportation vehicles provided the center frequency of the emission and the frequency at which the highest radiated emissions occur are greater than 24.075 GHz. Before designing the required UWB bandpass filter, certain specifications that must be considered are -10dB minimum rejection at 3.1 GHz, -10 dB minimum rejection at 10.6 GHz. fractional bandwidth of 110%, insertion loss less than 4 dB, return loss better then -10dB, a limited transmit power of -41dBm/MHz, the transmissions must occupy a bandwidth of atleast 20% of the center frequency. There are mainly four types of structures that are able to realize filters. The most popular and widely used structure is the microstrip structure with a Multi-Mode Resonator (MMR) and a parallel coupled line at each end of the network. The second type is a hybrid coplanar waveguide (CPW) with microstrip structure. Broadside coupled microstrip is the third type whereas a combination of lowpass and highpass filter is the fourth type. A new fabrication technique, such as Low Temperature Co-fire Ceramic (LTCC), is applied in the UWB bandpass filter designs. Designing miniaturized high selectivity UWB bandpass filters with deep attenuations at upper and lower stopband is not found straightforward. Therefore many practices to develop a perfect filter are being done in this area. Filter Bandwidth improvement techniques are tapped input, proper impedance transformation, low dielectric constant material or thicker substrate, multiline couplers, sufficient number of resonator sections, half- wavelength separated shorted resonators and utilizing defected ground structure (DGS). To analyze the performance of the filter its insertion loss, return loss, group delay, out of band rejection capability and fractional bandwidth are measured.

2. LITERATURE SURVEY
The latest research of 2017 in the field of millimeter-wave bandpass filter designing shows certain new miniaturization techniques that uses two on-chip mm wave band-pass filters in relation with broadside coupled meander-line resonator (BCMLR) and interdigital resonators [4]. It is made using a standard 0.1 µm GaAs technology. This selection provides a remarkable harmonic suppression for more than 40 dB. In the beginning of the new century, FCC released the UWB from 3.1 to 10.6 GHz for the use of indoor and handheld applications and 22 GHz to 29 GHz for automotive radar system. Since then a lot of challenges have been overcome but still due to the demands of the new era like compatibility and compactness better filters are required. In 2003, the bandwidth of the passband for UWB filters extended from 40% to 70%. In 2004, a ring resonator with a stub was proposed which shows a bandwidth of 86.6% but still the required bandwidth of 110% was not achieved. In 2005, mainly four types of structures were introduced that were able to realize a filter namely, microstrip multi-mode resonator, CPW, broadside coupled CPW and combination of highpass and lowpass [9]. In 2006, Microstrip based UWB filters were further improved in terms of designs of filters. In 2007, WLAN was introduced. It covered some portion of the ultra-wide band, so a sharp notch stop band filter became an urgent requirement. In 2009, many new notch stopbands were introduced which reduced the interference from WLAN. In 2010, tight coupling in the filters was used widely in order to cover and maintain the whole band. In 2011, many low cost and easy integration structures were developed as the size of the antenna started becoming small and small. In 2013, many scholars used integrated resonators in their filter design. In 2014, Out of

band performance of the filter was improved. In 2016, the fight to get a better filter that is much smaller in size and can attenuate the unwanted frequencies immediately at the edges of the passband continues. So now a days milimetre wave UWB compact filters are a new addition that uses better manufacturing technology with enhanced compatibility.

3. PROPOSED FILTER DESIGN

A new filter design is proposed that can work in the frequency range from 22 GHz to 29 GHz to meet the FCC specifications. RT/duroid 6002 is taken as its substrate which has an effective dielectric constant of 2.94. The substrate thickness is 0.127 mm and RT/duroid 6002 possesses a loss tangent of 0.0012.

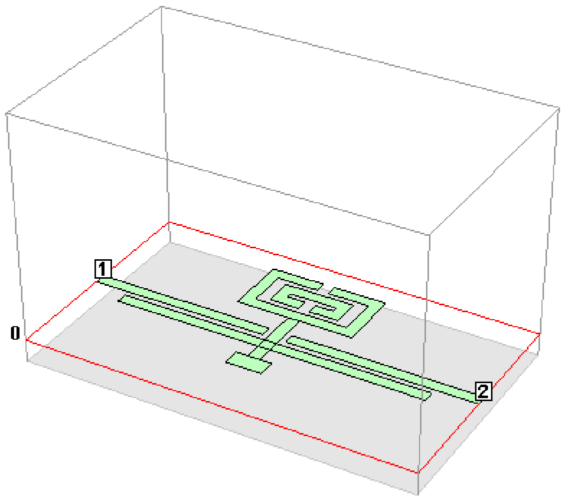

Fig.1. Three Dimensional View of UWB Bandpass Filter using Microstrip line and CSRRs

Fig.1 shows the arrangement of microstrip line and complimentary split ring resonators in the circuitry. Here the numbers marked as 1 and 2 denotes the input port and the output port respectively and the number 0 denotes the ground plane. The segment above the structure is air. Actually the top of the analysis box is a metal so it should be far away from the circuit inside it to avoid coupling. This filter design is a combination of Milli-meter wave UWB bandpass filter using parallel coupled microstrip line with two shunt ring resonator enclosed in one another and a shunt stepped-impedance open-circuited stub which is loaded at the center between the coupled line sections and complementary split ring resonators (CSRRs). The complimentary split ring resonators are attached to get the sharp attenuations at the edges of the spectrum. The even and odd mode impedances of parallel coupled lines at the input and output feed lines are defined by Z_Θ and Z_0 respectively. The electrical length (Θ) of the parallel-coupled lines is a quarter-wavelength at the mid-band frequency. The filter has the advantages of low insertion loss, compact size, high selectivity and excellent out-of-band performance. Therefore, the filter appears attractive for use in millimeter-wave applications. The proposed filter is actually a combination of two already designed filters [2,3]. One of the filter is design using shunt ring resonator in place of complimentary split ring resonators and it has been successfully fabricated and measured. It possesses an excellent agreement between the expected and measured results.

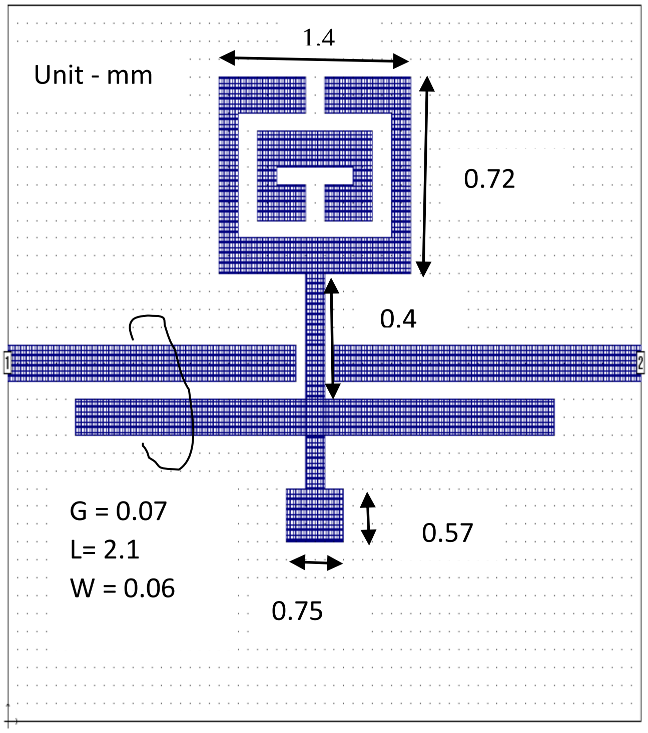

Fig.2. Geometry of Proposed Bandpass Filter using Microstrip line and CSRRs

The new design differs from the already proposed design in the sense that it contains complimentary split ring resonators in place of a simple ring resonator. Its design could be verified using EM simulation. A standard 0.18-um CMOS technology could be used to implemented and develop different types on millimeter-wave filters. On the other hand, low temperature co-fired ceramic technology (LTCC) is generally used to develop MMW bandpass filter. A MMW bandpass filter is proposed using a rectangular waveguide employing microstrip-to-waveguide transducer.

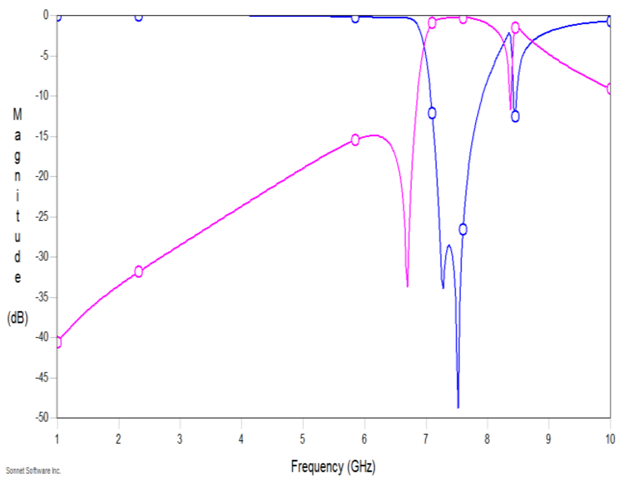

Fig.3. S-Parameter characteristics of the proposed filter in the 3 GHz to 10 GHz range.

Although the filter is designed to work in 22 GHz to 29 GHz range but for a comparative study its outcome in the 1 GHz to 10 GHz range is depicted in Fig.3.

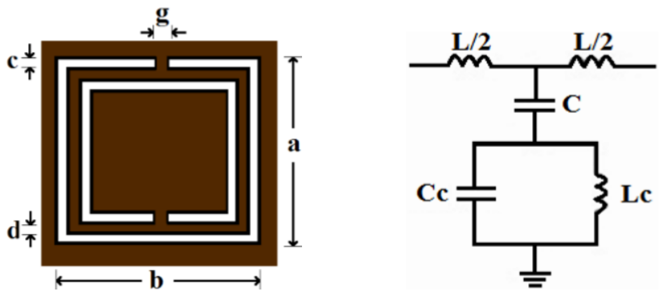

Fig.4. Topology of the CSRR cell and its equivalent circuit model

In Fig.4, the topology of the CSRR cell is shown [5]. Its equivalent circuit representation is also done to show its arrangement.

Table 1. Characteristics of Etching Cells Of CSRRs in the Ground Plane

Structure no.	**1**	**2**	**3**	**4**
a (mm)	2.5	3.5	3.5	3.9
b (mm)	2.5	3.5	3.5	3.9
c (mm)	0.2	0.2	0.2	0.2
d (mm)	0.2	0.7	0.1	0.1
g (mm)	0.1	0.1	0.1	0.1
f_c (GHz)	10.3	7	5.6	5
f_o (GHz)	5.5	3.65	2.95	2.55
BW (GHz)	10	6.7	5.3	4.7

The CSRR element presented as a new particle can produce a negative effective permittivity at resonance frequency depending on its size. This particle is excited by an axial time varying electric field instead of an axial magnetic field as in the case of split ring resonator (SRR). The transmission zero at the lower edge is generated and controlled by the shunt stepped-impedance resonator while the transmission zero at the upper edge is generated and controlled by the shunt ring resonator. These two transmission zeros increase the selectivity of the filter at both edges of the passband.

4. CONCLUSION

The UWB band pass filter proposed in this paper with an additional use of complimentary split ring resonator provides high selectivity at both edges of the UWB passband without increasing the degree of the filter. This filter is designed to work in frequency band of 22GHz to 29GHz in order to meet the FCC specifications. It has two parallel coupled line sections with open circuited stub at one end and complimentary split ring resonators at the other end. This provides it the characteristics of high selectivity. Its future scope involves persistence of such improved filters in automotive radar and satellite communication systems.

5. REFERANCES

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